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COMMITTEE PAPERS SUPPLEMENT

APPENDIX 2.5

ANNEX H

ILAC COMMITTEE 2

WORKING GROUP 4

UNCERTAINTY OF MEASUREMENT IN TESTING

EXAMPLES OF ESTIMATION OF
UNCERTAINTY OF MEASUREMENT IN TESTS
BASED ON THE ISO/TAG4 APPROACH

ANNEX H

EXAMPLES OF ESTIMATION OF UNCERTAINTY OF MEASUREMENT IN TESTS BASED ON THE ISO/TAG4 APPROACH

CONTENTS

Estimation of Uncertainty of Measurement in Tensile Testing

NAMAS

1 BASIS OF MEASUREMENT

1.1 The tensile strength of a metal is determined by applying a displacement to a testpiece, often of circular cross section, in a machine specially equipped to grip the testpiece, apply a displacement at a controlled rate and measure the maximum force required to break the testpiece.

1.2 The tensile strength is reported as the maximum force exerted during the test divided by the original cross-sectional area of the testpiece.

1.3 The test machine must be verified and graded for force measurement as specified by the relevant standard - the grading is a function of the relative error of accuracy, repeatability, zero and the resolution of the readout device. This may be a computer printout, a digital indicator, a dial indicator or a chart record.

1.4 The cross-sectional dimensions of the testpiece must be measured prior to test; normally done with a micrometer.

1.5 The temperature of test and the rate of straining or loading are required to be maintained within set limits during the test.

1.6 This example considers the uncertainty arising from the test itself and no account is taken of uncertainty due to sample-to-sample variation.

2 MATHEMATICAL MODEL

$$R_m = f(A, F, T, \dot{\varepsilon})$$

where R_m is tensile strength in N/mm^2, A is cross-sectional area in mm^2, F is force in N, T is temperature and $\dot{\varepsilon}$ is strain rate.

At defined values of temperature and strain or loading rate the tensile strength is given by:-

$$R_m = \left(\frac{F}{A}\right)_{T,\dot{\varepsilon}}$$

3 CONTRIBUTORY COMPONENTS TO OVERALL UNCERTAINTY

3.1 The primary components contributing to the overall uncertainty are:-

u_A: the uncertainty in measurement of area,
u_F: the uncertainty in measurement of force,
u_T: the uncertainty of the correction for the effect of temperature,
$u_{\dot{\varepsilon}}$: the uncertainty of the correction for the effect of strain rate.

3.2 These components may themselves be composed of contributions resulting from the method of measurement in each case. The quantification of the contributions may be by:-

(a) Estimation; eg from calibration data, reference data, manufacturers' specifications or on the basis of previous experience of the behaviour of the material or equipment.

(b) Evaluation from repeated measurements using statistical techniques.

4 UNCERTAINTY IN MEASUREMENT OF CROSS-SECTIONAL AREA, u_A:-

4.1 Example for measurement of a circular testpiece of 10.00 mm nominal diameter using a micrometer calibrated to BS 870.

4.1.1 Uncertainty in area measurement associated with micrometer, u_{mic}:-

Micrometer calibration uncertainty - taken from the calibration certificate.
Quoted uncertainty = ± 0.003 mm at 95% confidence level.

Uncertainty in micrometer calibration source - based on knowledge of calibration data for the gauges used, = ± 0.0001 mm (insignificant compared with calibration uncertainty - ignore).

Drift/wear in micrometer since last calibration - based on history of calibration data: ≤ ±0.0002 mm (insignificant compared with calibration uncertainty - ignore).

Standard uncertainty component: u_{mic} = ±0.003/2 = ±0.0015 mm

4.1.2 Operator-uncertainty in measurement of testpiece diameter, estimated on basis of previous experience of repeated measurements: = ±0.01 mm at 95% confidence level.

Standard uncertainty component: u_{opm} = ± 0.005 mm.

4.1.3 ∴ Uncertainty in diameter measurement, u_{dia}:-

$$u_{dia} = \sqrt{u_{mic}^2 + u_{opm}^2}$$

$$u_{dia} = \pm 0.0052 \text{ mm}$$

4.2 Overall uncertainty of area measurement, u_A:-

$$u_A = \frac{[(10.0052)^2 - (10.00)^2]\pi/4}{(10.00)^2\pi/4} = \pm 0.104\%$$

5 UNCERTAINTY IN THE MEASUREMENT OF FORCE, u_F:-

5.1 Testing machine uncertainty - based on the assumption that where the equipment used has limits defined by a verification standard the uncertainty is defined by the Class. In this case the machine was verified to BS EN 10002-2 Class 1.0; this procedure involves some repeated measurements and the uncertainty was taken as ±1.0% at the 95% confidence level.

Standard uncertainty component: = ± 0.5%

5.2 Proving device uncertainty - based on the assumption that where the equipment used has limits defined by a verification standard the uncertainty is defined in by the Grade. In this case the proving device was verified to BS 1610 Part 2 - Grade 1.0, ie uncertainty taken as ±0.2% at 95% confidence level.

Standard uncertainty component: = ± 0.1%

5.3 Operator - uncertainty in reading force value:

Assuming an analogue scale and an ability to read to 1/5 of a division.
Taking a 200 kN scale where 1/5 division = 0.1 kN.
At full scale, ± 0.1 kN ≡ ± 0.05%.

However, the test piece will not necessarily fail at full scale, but the range selected should be such that it will be unlikely that less than 1/5 of full scale will be indicated at failure. Therefore, assume that failure occurs at 1/5 of full scale, ie at 40 kN.

At 40 kN, ± 0.1 kN ≡ ± 0.25%. Assume rectangular distribution;

∴Standard uncertainty component: = $\pm 0.25/\sqrt{3}$ = ±0.144%

5.4 Overall uncertainty of force measurement, u_F:-

$$u_F = \sqrt{(0.5)^2+(0.1)^2+(0.144)^2}$$
$$= \pm 0.53\%$$

6 UNCERTAINTY IN THE CORRECTION FOR TEMPERATURE

6.1 For a tensile test at room temperature this correction and the uncertainty associated with it can be safely assumed to be negligible.

7 UNCERTAINTY IN THE CORRECTION FOR STRAIN RATE

7.1 Even at room temperature some metals may exhibit a degree of sensitivity of tensile strength to strain rate over the range permitted by the standard. However the standard does not call for any correction to be made. This means that the correction is zero but that the associated uncertainty would be estimated from knowledge of the material behaviour over the permitted range of strain rate. Provided that there is access to relevant data then an estimate of the contribution from this source can be included in the evaluation of the overall uncertainty of the result.

7.2 In this example the material is assumed to be insensitive to variation in strain rate over the permitted range and that the uncertainty from this source can be ignored.

8 COMBINATION OF COMPONENT UNCERTAINTIES IN MEASUREMENT OF TENSILE STRENGTH

8.1 The final combination using the root sum square method involves the two primary components.

Combined standard uncertainty:-

$$u_{R_m} = \sqrt{u_A^2 + u_F^2}$$

$$= \sqrt{(0.104)^2 + (0.53)^2}$$

$$= \pm\ 0.54\%$$

8.2 In this example the tensile strength is given by:-

$$R_m = \frac{40.10^3}{\pi\left(\frac{10}{2}\right)^2} \quad N/mm^2$$

$$= \underline{509.6} \quad N/mm^2$$

The standard uncertainty is ± 0.54% of this value, ie ± 2.75 N/mm^2.
The expanded uncertainty (k=2) is therefore: ± 5.5 N/mm^2.

9 STATEMENT OF UNCERTAINTY

9.1 Unless otherwise specified the result of the measurement should be reported together with the uncertainty as follows:-

Measured value of tensile strength	509.3 N/mm^2
Uncertainty of measurement	± 5.5 N/mm^2

The reported uncertainty is based on an estimated standard deviation and a coverage factor of k = 2 which provides a level of confidence of approximately 95%.